GREEN CHEMISTRY: AN OVERVIEW

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Subject: Green Chemistry /INTRODUCTION TO GREEN CHEMISTRY

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INTRODUCTION TO GREEN CHEMISTRY

- Definition: The design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances.“

- Importance: Discuss the environmental, economic, and social benefits.

Green Chemistry is the utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture and application of chemical products *.

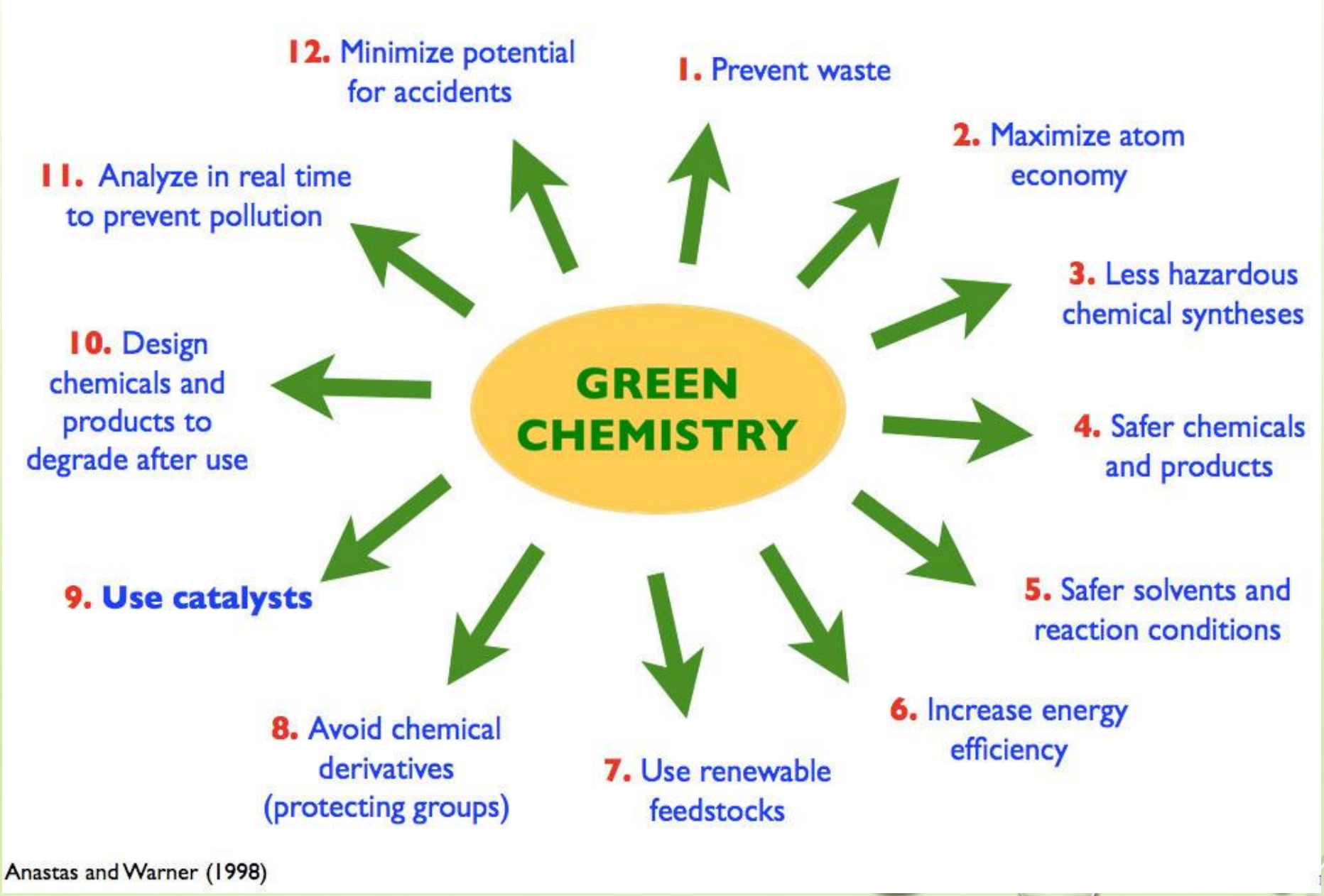
Green chemistry seeks to reduce pollution at source.

Environmental chemistry focuses on the study of pollutant chemicals and their effect on nature.

Green Chemistry Is About…

- Waste
- Materials
- Hazard
- Risk
- Energy
- Environmental Impact
- COST

The Twelve Principles of Green Chemistry:



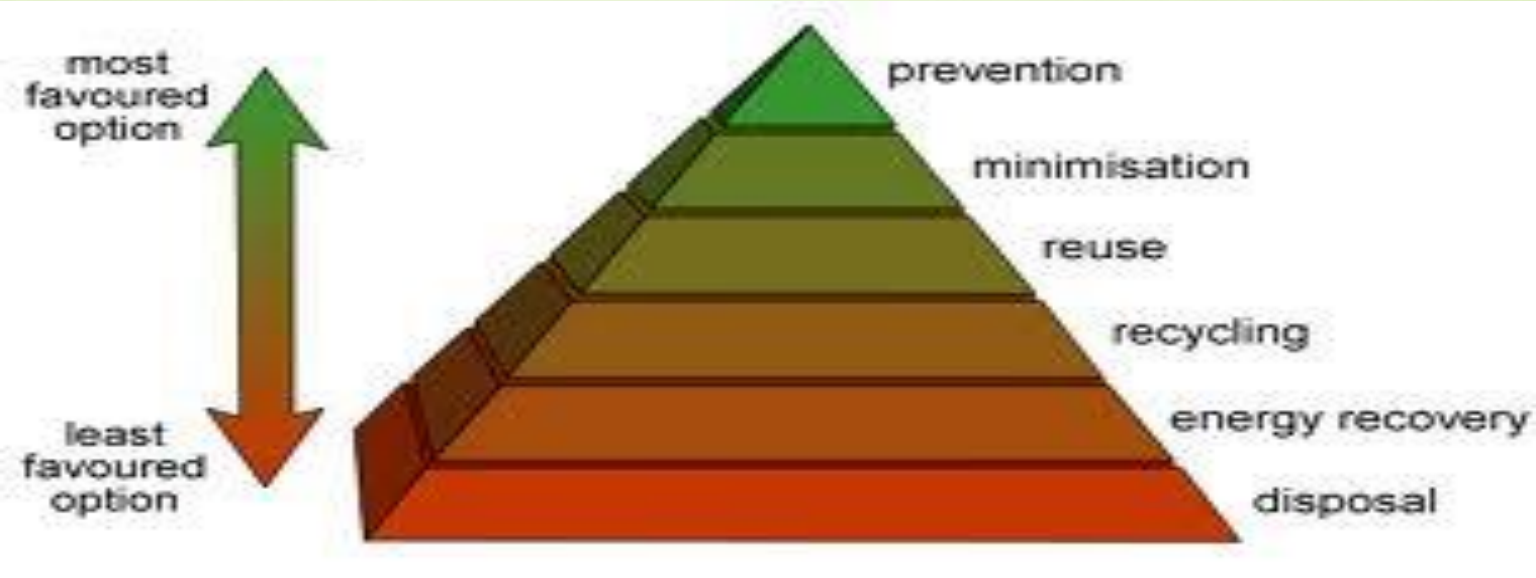
Anastas and Warner (1998)

1 . Prevention of Waste/By-Products

Waste

unreacted starting materials
solvents
by- products

- discharged causes pollution
- Cost -treatment and disposal



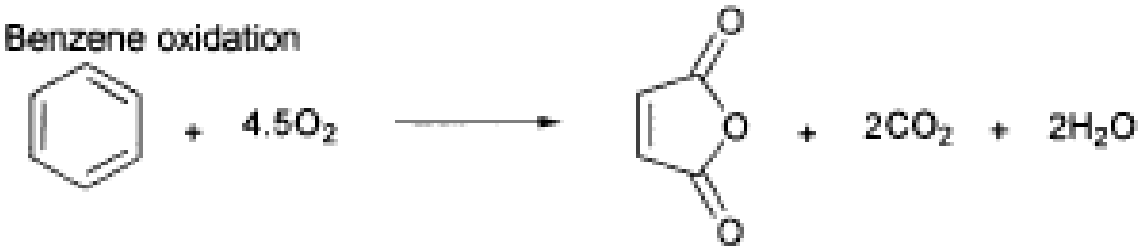
2. Maximize use of materials -Atom Economy

A reaction is considered green if there is maximum incorporation of starting materials and reagents in the final product

In an ideal chemical process, the amount of starting materials or reactants Equals the amount of all products generated and no atom is wasted.

$$\% \text{ Atom Economy} = 100 \text{ X } \frac{\text{Relative molecular mass desired products}}{\text{Relative molecular mass of all reactants}}$$

Benzene oxidation



Formula weights

78 4.5 × 32 = 144 98

% atom economy = 100 × 98/(78 + 144) = 100 × 98/222 = 44.1%

Butene oxidation

Formula weights

56 3 × 32 = 96 98

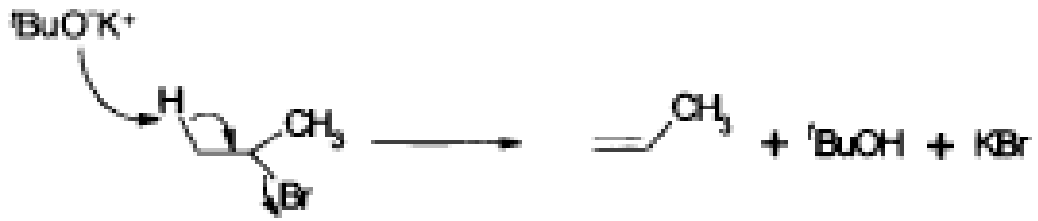
% atom economy = 100 × 98/(56 + 96) = 100 × 98/152 = 64.5%

Atom economy for maleic anhydride production routes

Relative molecular masses

74	36.5	92.5	18

Atom economy = 100 x 92.5/(74 + 36.5) = 83.7%



Relative molecular masses

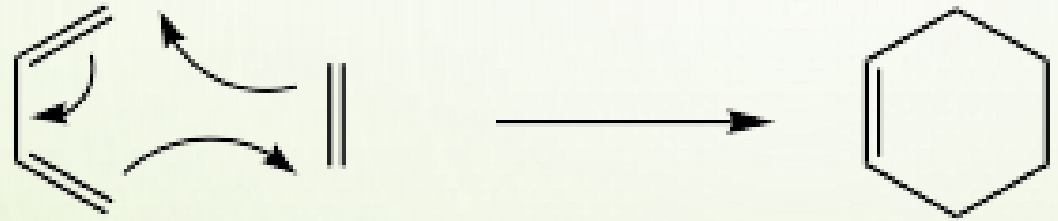
112	122	42

Atom economy = 100 ×42./(112 + 122) = 17.9%

Base catalysed elimination from 2-bromopropene

Green Synthesis

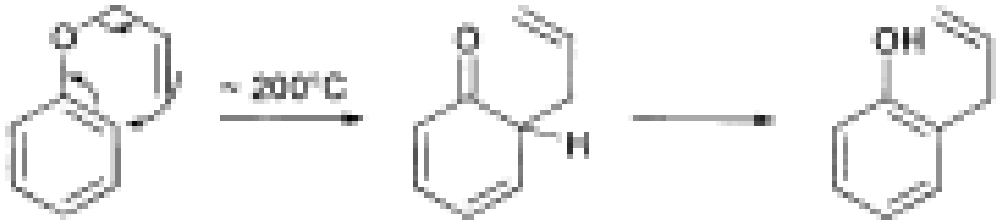
Addition Reactions



diene + dienophile

Atom Economy = 100 %

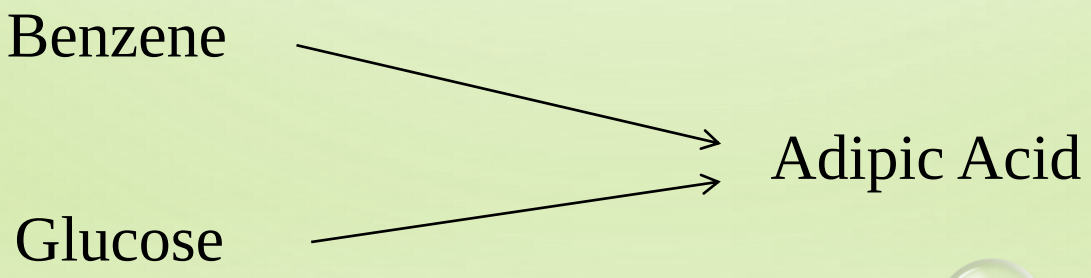
Claisen Rearrangement reaction



Atom Economy = 100 %

3. Minimisation of the use and production of hazardous and toxic chemicals.

- Wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to people or the environment



4. Design safer products

- ***Chemical products should be designed to effect their desired function while minimising their toxicity.***

With the advancement of technology, the designing and production of safer chemicals has become possible

Eg:- An unsafe drug is *Thalidomide*, introduced in 1961 for lessening the effects of nausea and vomiting during pregnancy.

But children born to women taking this drug suffered birth defects .Subsequently the use of that drug was banned

5. Safer solvents and auxiliary substances

•The use of auxiliary substances (e.g., solvents or separation agents) should be made unnecessary whenever possible and innocuous when used.

Many solvents used in traditional organic syntheses are highly toxic

Green chemistry approach:

- **Use supercritical carbon dioxide as a solvent**
- **Reactions carried out using ordinary water as solvent**
- **Ionic liquids are excellent solvents for many materials, and they can be recycled.**
- **Without the presence of any solvent**

Design for Energy efficiency.

•Energy requirements of chemical processes should be recognised for their environmental and economic impacts and should be minimised.

Ways to conserve energy: green method

1.Using catalysts
2. Using microwave heating
3. Using ultrasound
4. Photochemical reaction using solar energy

Use renewable feedstocks

Most organic compounds used as feedstock are derived from petroleum, a nonrenewable resource (*depleting*)

A green approach is to replace these petrochemicals with chemicals derived from biological sources

The refining of organic compounds from these plant-derived materials, sometimes called **biomass,** is less polluting than the refining process for petrochemicals.

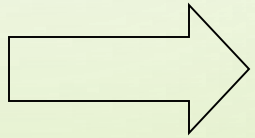
Many pharmaceuticals, plastics, agricultural chemicals can now be produced from chemicals derived from biomass

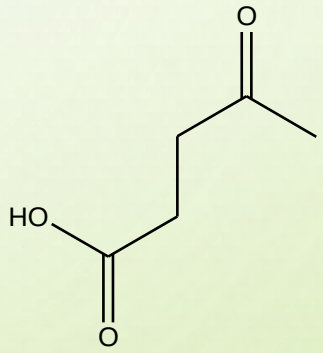
Raw Materials from Renewable Resources:

Paper mill sludge

Agricultural residues, Waste wood

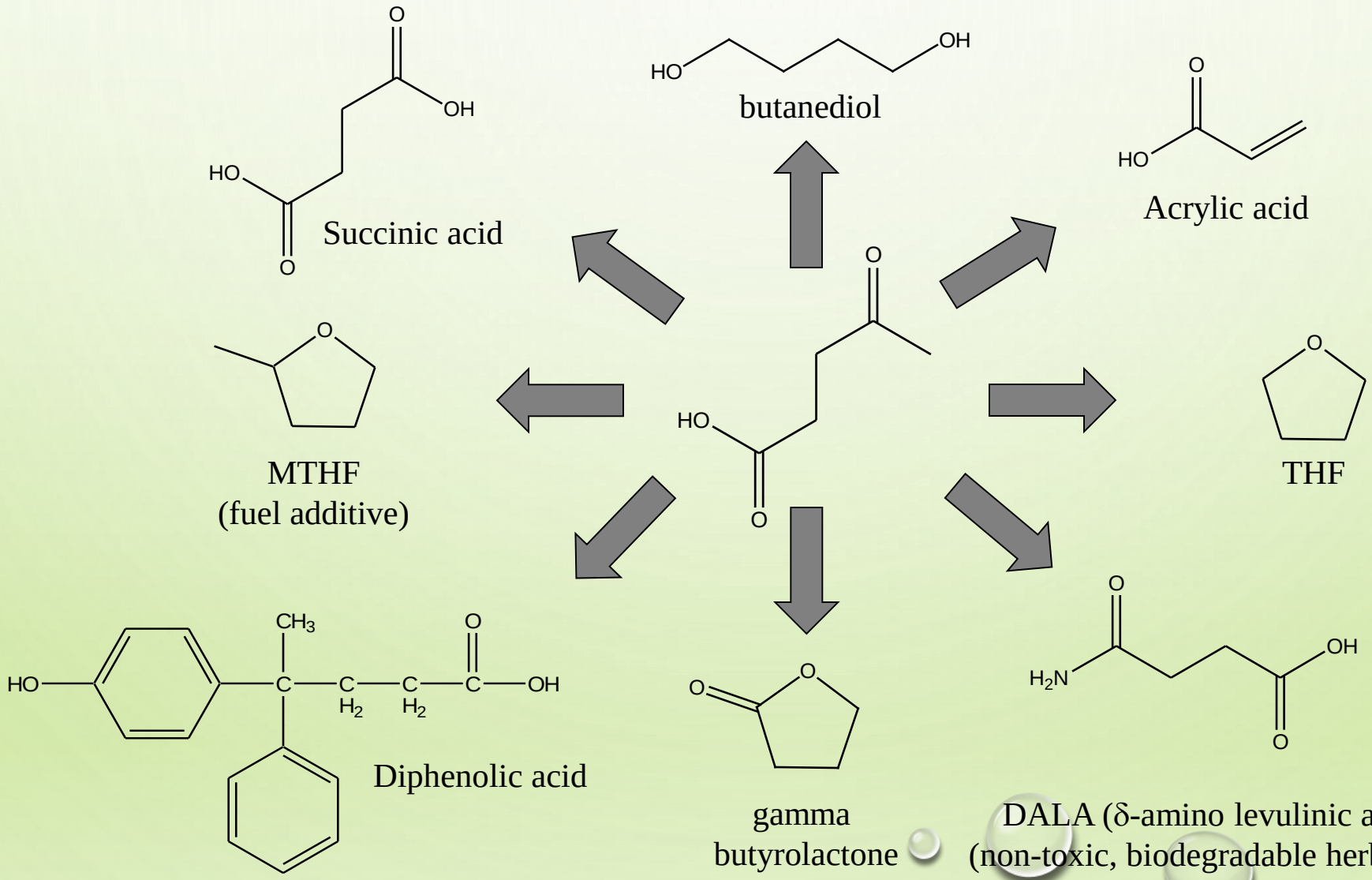
Municipal solid waste and waste paper





Levulinic acid

Levulinic acid as a platform chemical

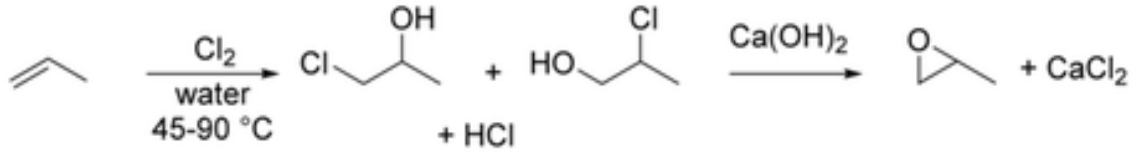


Use of shorter synthetic routes

•Unnecessary steps should be minimised or avoided if possible, because such steps require additional reagents and can generate waste.

Industrial routes to propylene oxide.

Chlorohydrin Process (oldest):



Overall yield and atom economy will decrease for large synthetic routes

Use catalysis

- By the use of catalyst the need for large quantity of reagents can be avoided that leads to waste stream
- By increasing the rate of attainment of equilibrium through lowering the activation energy, **catalysts reduce the energy requirement of a process**
- Waste is generally reduced compared to the non-catalytic alternative and better utilization of starting material.
- Better Yield and Atom economy
- Reaction become feasible in cases where no reaction is normally possible
- Green Nanocatalyst like gold nano particles,Silver nano particles etc are very efficient in organic synthesis
- Biocatalysis using enzymes are also very effective in green synthesis

Design for degradation

Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.

The problem is encountered mainly in insecticides and polymers.

Real-time monitoring/control for Pollution Prevention

• Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.

Inherently Safer Chemistry for Accident Prevention

- **Substances and the form of a substance used in a chemical process should be chosen to minimise the potential for chemical accidents, including releases, explosions, and fires.**

Bhopal Tragedy – 1984

methyl isocyanate (MIC) accidentally released

15,000 people died, many injured

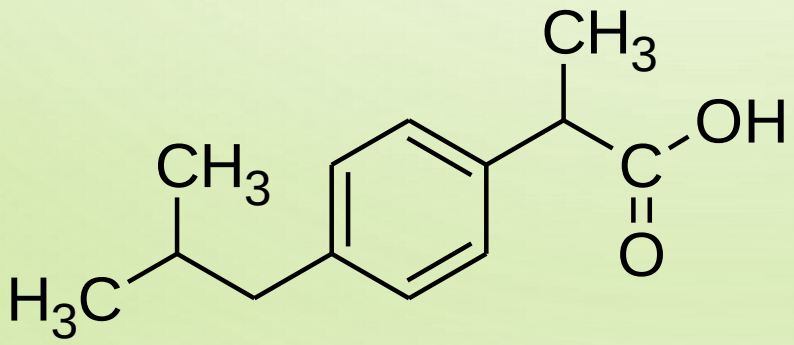
- **The manufacturing plants should be designed to eliminate the possibility of accidents during operation.**

Green Synthesis

❖The Synthesis of Ibuprofen

Widely used chemical for Pharmaceutical drugs, in various kinds of analgesics (Pain killers)

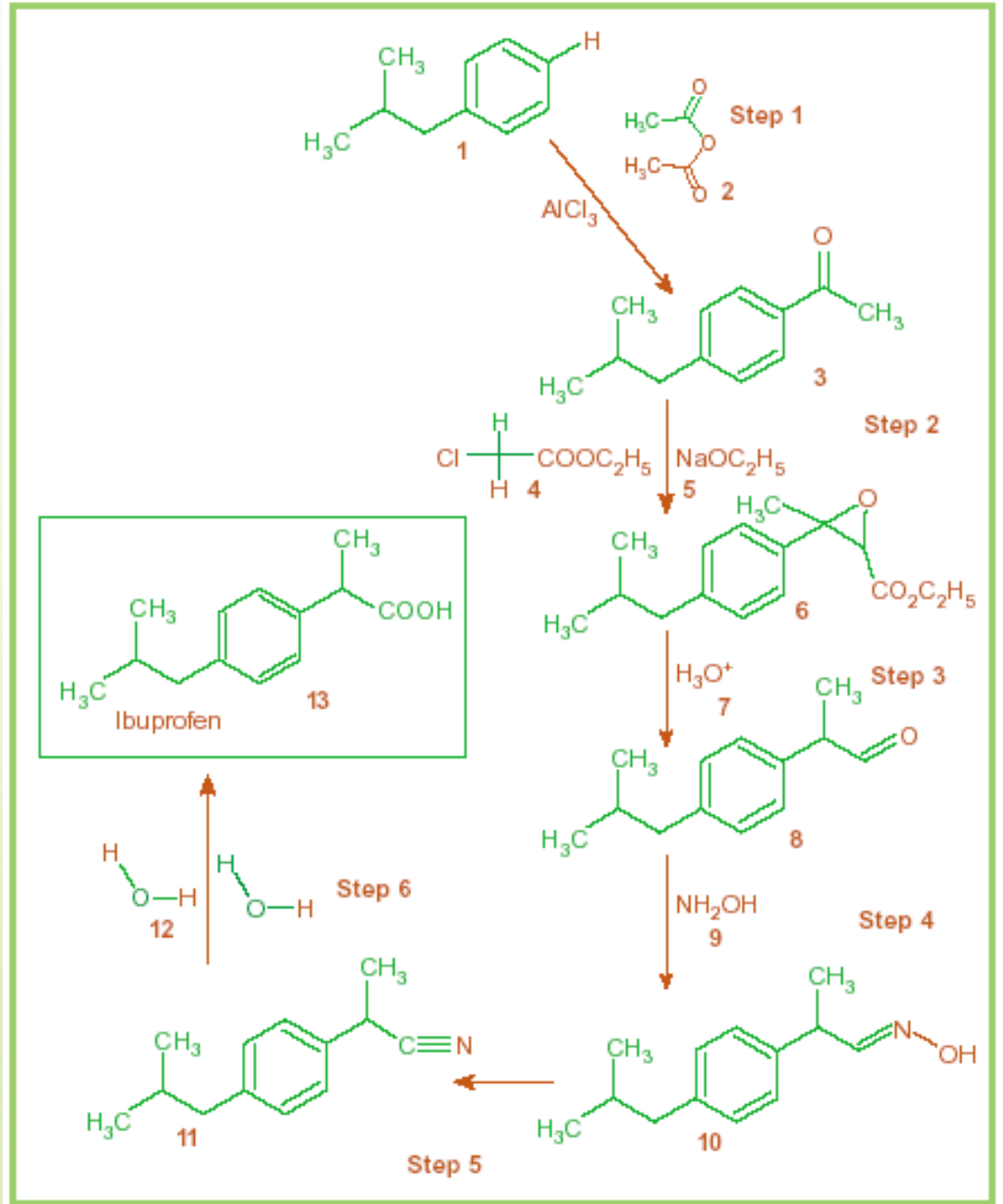
- Advil, Motrin, Medipren
- 28-35 million pounds of ibuprofen are produce each year
- (37-46 million pounds of waste)



2-(4-isobutylphenyl)propanoic acid

Brown Synthesis

Overall atom economy is 40%.



SCHEME 1. The Boots Company Synthesis of Ibuprofen—The Brown Synthesis